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CENÁRIOS DE ÍNDICES EXTREMOS DE PRECIPITAÇÃO PARA O MUNICÍPIO DE CRATEÚS, SEMIÁRIDO CEARENSE

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1 RESUMO

Este estudo analisou dois índices pluviométricos (precipitação anual total e a frequência de eventos de chuva ≥100 mm) em Crateús, semiárido cearense, comparando projeções de dois Modelos Climáticos Regionais (Eta-HadGEM2-ES e Eta-MIROC5) para o clima atual com dados observados de um posto pluviométrico centenário. Também foram avaliadas as projeções dos modelos para o clima futuro sob os cenários RCP 4.5 e 8.5, em horizontes de curto (2006-2040), médio (2041-2070) e longo prazo (2071-2099). Ambos os modelos representaram bem o histórico (1976-2005), simulando sete eventos R100mm, próximos aos oito observados. As projeções apontam aumento das chuvas até cerca de 2050, seguido de queda a partir de 2060, independente do RCP. O cenário mais pessimista (HadGEM2-ES sob RCP8.5) indicou os menores índices de precipitação após 2060, com uma variação de até -19,4% em relação ao histórico. Esses resultados são fundamentais para a gestão hídrica e o planejamento de políticas públicas em uma região com escassez hídrica e vulnerabilidade climática.

Keywords: Mudanças climáticas, Modelo Eta, Regiões secas.

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2 ABSTRACT

This study analyzed total annual precipitation and the frequency of rainfall events ≥100 mm in Crateús, a semiarid region of Ceará, by comparing projections from two regional climate models (Eta-HadGEM2-ES and Eta-MIROC5) for the current climate with observed data from a centennial rain gauge station. The models' projections were also evaluated for future climate under the RCP4.5 and RCP8.5 scenarios across short (2006--2040), medium (2041--2070), and long-term (2071--2099) horizons. Both models effectively represented the historical period (1976--2005), simulating seven R100 mm events that were close to the eight events observed. Projections indicate an increase in rainfall until approximately 2050, followed by a decline after 2060, regardless of the RCP scenario. The most pessimistic scenario (HadGEM2-ES under

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RCP8.5) projected the lowest precipitation indices after 2060, with a variation of up to -19.4% compared with the historical period. These results are crucial for water resource management and public policy planning in regions characterized by water scarcity and climate vulnerability.

Keywords: Climate change, Eta model, Dry regions.

3 INTRODUCTION

Knowledge of annual precipitation indices (APIs) is essential for water resource management. In drylands, which include the semiarid region of Brazil, the high spatial and temporal variability of rainfall (Andrade *et al*., 2016) makes it even more important to obtain historical records of these indices. Planning water infrastructure that will meet various needs (human supply and animal watering, agriculture, industry) and the management of agricultural soils requires the systematization of these APIs, such as total annual precipitation (PRCPTOT) and the number of days per year with precipitation equal to or greater than 100 mm (R100 mm).

On the basis of historical records, projections of future scenarios for IAP have been constructed via global climate models (*global climate models* – GCMs) and regional climate models (*regional climate models* – RCMs). In semiarid regions, these projections have been used to investigate how climate change impacts the availability of water resources (Rodrigues *et al*., 2024) and the demand for water for irrigation (Gondim *et al*., 2018). The reduced water reserves in the Sertões de Crateús Hydrographic Basin, even in years of satisfactory supply at the state level, reinforce the vulnerability of the area to the effects of climate change (Secretaria dos Recursos Hídricos, 2024).

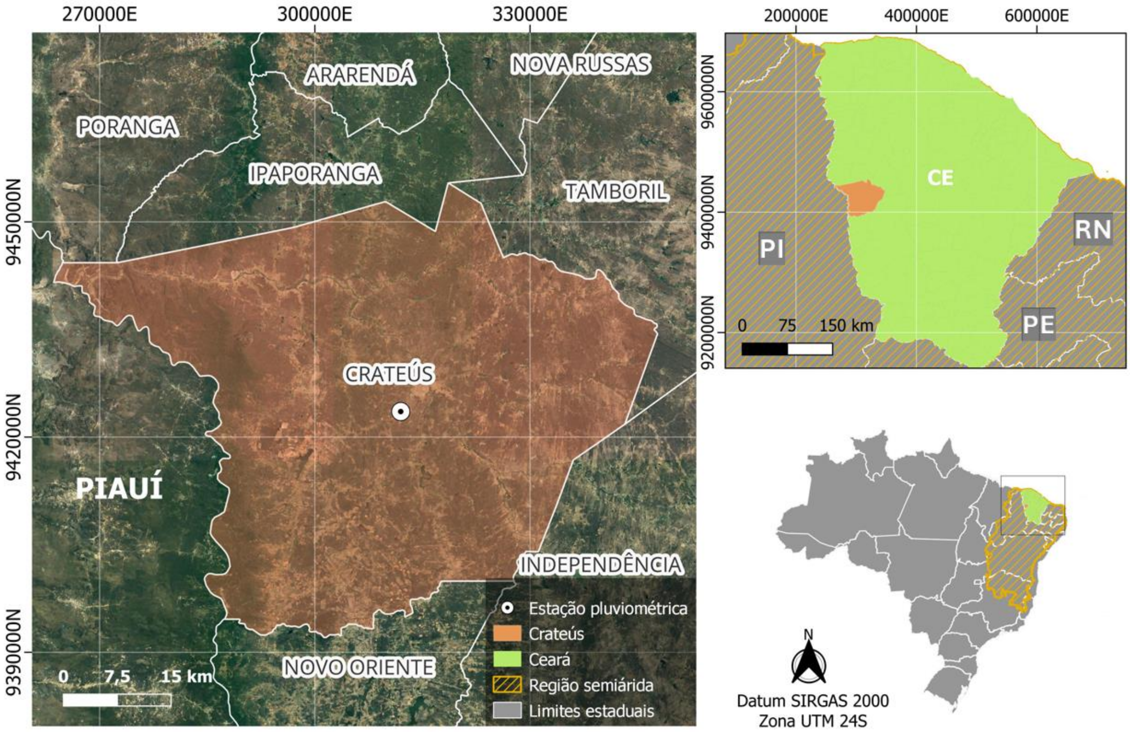
Therefore, this work aims to analyze the PRCPTOT and R100 mm indices of a century-old historical series of precipitation from a rain gauge located in the municipality of Crateús, a semiarid region of Ceará, and the PRCPTOT and R100 mm projections derived from the RCMs Eta-HadGEM2-ES and Eta-MIROC5 (Chou *et al*., 2014) in the representative concentration pathways of greenhouse gases (RCPs) 4.5 and 8.5 (Gütschow *et al*., 2021) for *the* short (*2006--2040*), MEDIUM *(*2041--2070) and long-term (2071--2099) periods.

4 MATERIALS AND METHODS

4.1 Study area

This study was conducted in the municipality of Crateús (Figure 1), which belongs to the Sertões de Crateús Hydrographic Basin. The municipality has an area of approximately 2,985 km², with an average annual precipitation of 695 mm (for the period of 1992–2022, excluding the year 2008 due to the absence of records in January), a potential evapotranspiration of 1,900 mm (INMET, 2024), and is completely located in the Brazilian semiarid region.

Figure 1. Locations of the study area and the rainfall stations used.



4.2 Precipitation data

The precipitation data used come from two rainfall stations in Crateús, whose characteristics are described in Table 1 (ANA, 2024; Funceme, 2024).

Table 1. Data from the meteorological stations used

Code	Municipality	Operator	Registration period	Latitude	Longitude
540020	Crateus	DNOCS/Funceme	12/1910 to 06/2023	-5.2108	-40.7036
A342	Crateus	INMET	From 07/2023	-5.1866	-40.6722

As an exclusion criterion, only years without failures in the rainy season (January--May) were considered. For years with failures in the dry season, the historical average was used to fill in the missing values, since, at this time of year, rainfall tends to be very low, with averages close to zero. This approach ensured a consistent and representative database for the period analyzed. Figure 2 shows the evolution of annual rainfall (mm) observed since 1911 (ANA, 2024). This centennial series of rainfall data represents a relevant hydrological record for the analysis of climate variability and extreme events in the Brazilian semiarid region (Nunes; Medeiros, 2020). Precipitation is concentrated in the months of January to May (Figure 3).

Figure 2. Historical precipitation series for the study area.

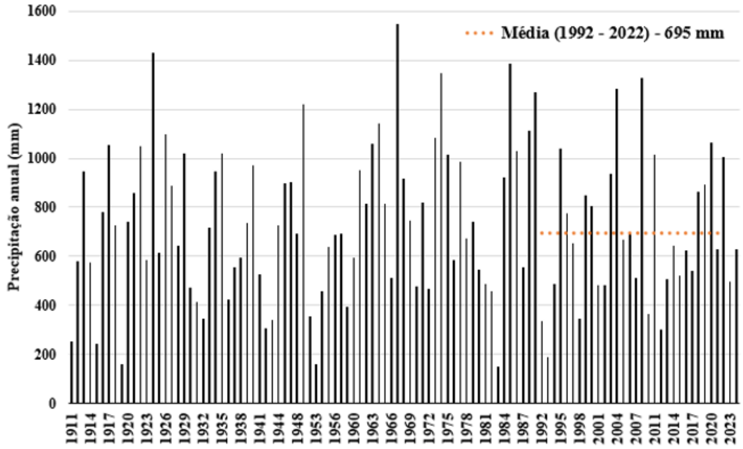
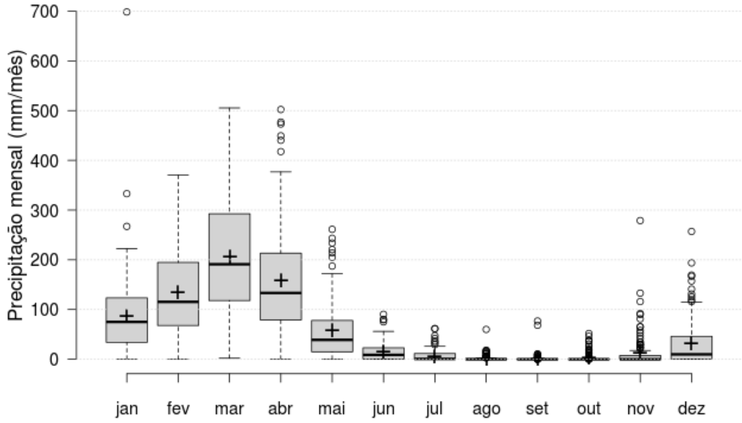


Figure 3. Annual distribution of precipitation in the study area.



4.3 Climate modeling data

The historical simulation was obtained from the Eta Regional Climate Model nested within the global models HadGEM2-ES and MIROC5. The data obtained on a 20 × 20 km grid (Mesinger *et al*., 2012; Chou *et al*., 2014 ; CNPq, 2024; Tavares *et al*., 2024) are daily data, which are distinguished by having been subjected to a bias reduction technique, which adjusts discrepancies between simulations and observations, making the projections more reliable.

Data are available for the period from 1976--2005 (historical simulation), which is considered the reference period or the current climate, and from 2006--2099, which is considered the future climate period. For the future period, the climate projections considered two greenhouse gas concentration scenarios, RCP4.5 and RCP8.5.

The following annual indices of precipitation-related climate extremes were used: annual total precipitation (PRCPTOT) and the number of days per year with precipitation equal to or greater than 100 mm (R100 mm). The indices are provided for the current climate scenario (1976–2005) and for the future climate scenario (up to 2099), segmented into the periods 2006– 2040, 2041–2070 and 2071–2099 (short, medium and long term, respectively).

5 RESULTS AND DISCUSSION

Initially, we assessed whether there was a change in the trend in the total annual precipitation observed between 1911 and 2024 (Figure 4), totaling 107 years with consistent records. From the nonparametric Mann–Kendall test, it is possible to statistically state (p value of 0.78) that there was no change in the trend in the annual accumulated precipitation in this observed period. The trend line (dashed red line in Figure 4) shows a low slope, which illustrates the absence of a trend.

Figure 4. Mann–Kendall test for trend analysis of total annual precipitation (mm).

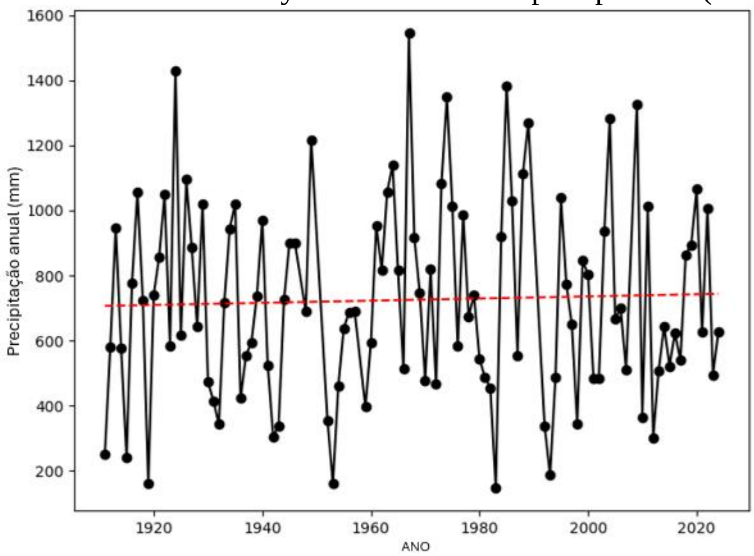
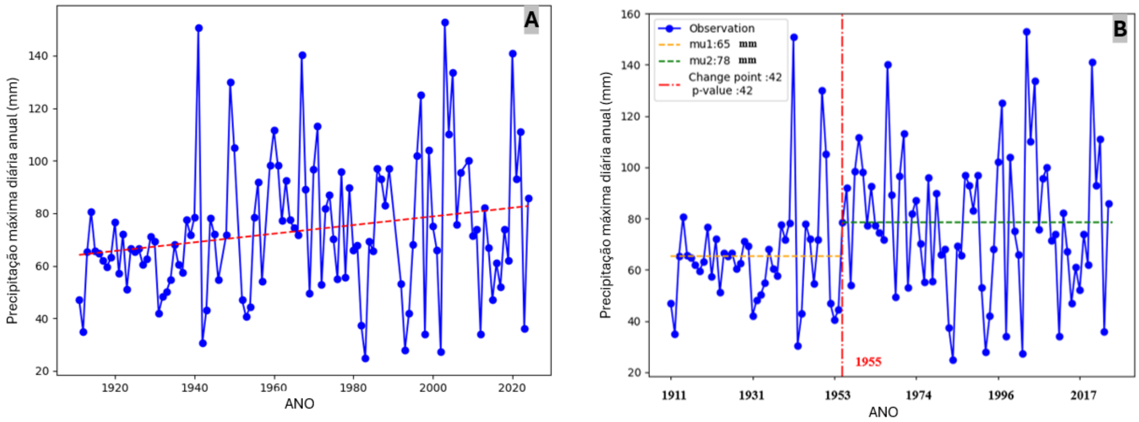


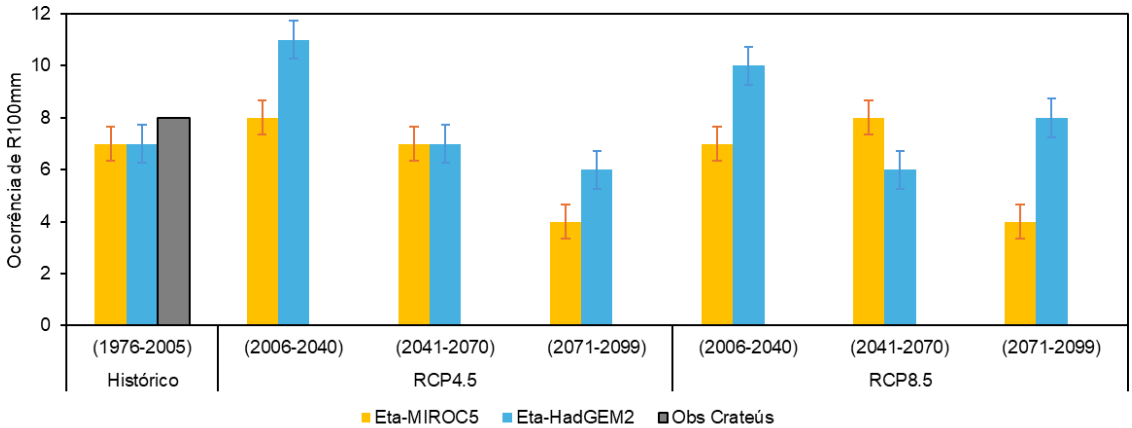
Figure 5 (A) shows the historical evolution of maximum precipitation events on an annual scale. The Mann–Kendall test indicates (p value of 0.023) an increasing trend (increasing trend line) in the maximum annual precipitation. The Pettitt homogeneity test (Figure 5 B) revealed that the year of trend change was 1955, which corresponds to the 42nd year with a consistent record of the series. Until 1954, the average maximum annual precipitation was 65 mm. From 1955 onward, this value reached 78 mm.

Figure 5. Mann–Kendall test for trend analysis of maximum annual precipitation (mm) (A) and Pettitt test for analysis of the year of change in maximum annual precipitation (mm) (B).



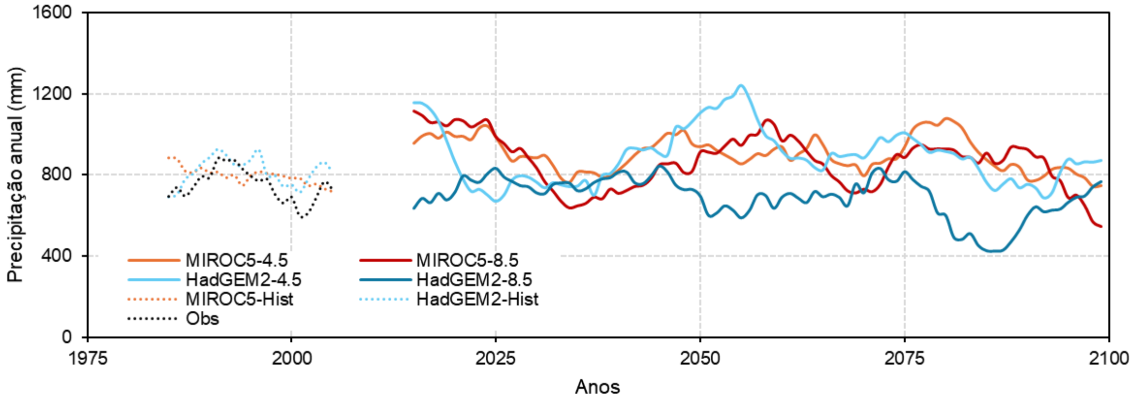
The analysis of the historical series of daily rainfall at the Crateús/Airport station (1976--2005) indicated the occurrence of eight daily events equal to or greater than 100 mm (R100 mm) for a total of 1658 rainfall records in this period, corresponding to 0.5%. Among these events, five (62.5%) occurred in the rainy season (February–May), one in November and two in January (prerainy season). Figure 6 summarizes the number of events observed in the present climate period and the model projections for the present and future climate periods (RCP4.5 and 8.5).

Figure 6. Occurrence of rainfall events equal to or greater than 100 mm (R100 mm).



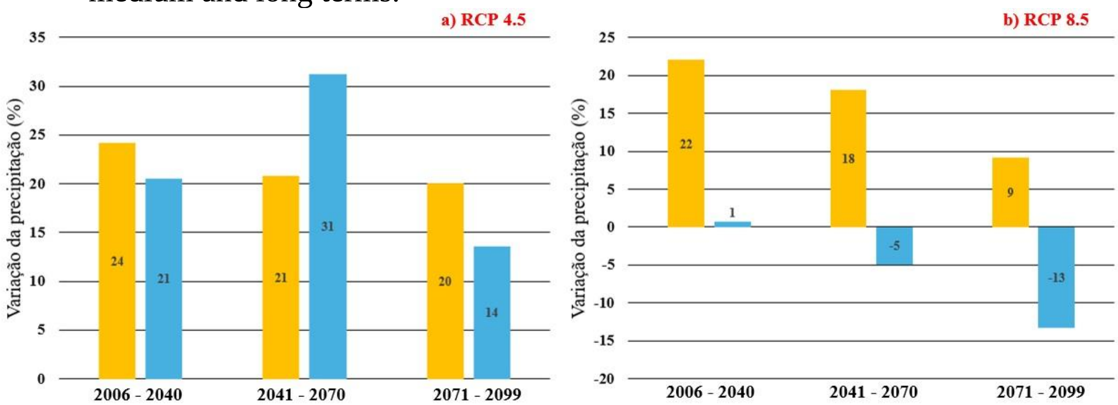
Historical simulations performed by the regional climate models Eta-HadGEM2 and Eta-MIROC5 demonstrated results very close to the observed data, with Eta-HadGEM2 presenting an overestimate of 7.6% and Eta-MIROC5 of 8.3% (Figure 7). In the RCP4.5 scenario, which adopts a scenario of stabilization of CO2 emissions after 2050, both models predict a significant increase in rainfall by 2040, with Eta-MIROC5 indicating an increase of 14.7% and Eta-HadGEM2 of 12.0%, values that also remain close.

Figure 7. Historical (1976--2005) and future (2006--2099) annual precipitation for the four climate scenarios



However, from the medium-term period (2041--2070), the results diverge (Figure 8), with Eta-MIROC5 continuing to indicate an increase in precipitation of 9.1% compared with the historical period, whereas Eta-HadGEM2 predicts a decrease of approximately 11.6%, especially under the most pessimistic scenario, RCP8.5 (Figure 8b). This last scenario is based on an increase in CO2 concentration until the end of the century.

Figure 8. Variation in future precipitation from the Eta-HadGEM2 (blue) and Eta-MIROC5 (yellow) models under the RCP4.5 (a) and RCP8.5 (b) scenarios in the short, medium and long terms.



Although the Eta-HadGEM2-ES and Eta-MIROC5 models represent the historical climate well, their projections are still subject to uncertainties inherent to climate models, such as limited spatial resolution and dependence on global model boundary conditions. Furthermore, the variability of extreme events may not be fully captured. Future studies may explore multiple models and statistical methodologies to reduce uncertainties, in addition to considering detailed regional impacts on Crateús' hydrology and water infrastructure.

The results of this study are crucial for water planning and the formulation of public policies aimed at climate resilience in Crateús. The increase in rainfall projected until 2050 may represent opportunities for expanding water capture and storage, whereas the downward trend after 2060 highlights the need for adaptation strategies, such as diversifying water sources, increasing water use efficiency, and strengthening water governance mechanisms. In addition, continuous monitoring of climate projections can support more dynamic and assertive decisions to mitigate the impacts of climate variability in the region.

6 CONCLUSION

Projections of future precipitation for the municipality of Crateús, in the semiarid region of Ceará, indicate possible increases in annual averages under the moderate emissions scenario (RCP4.5) and greater uncertainty under the most extreme scenario (RCP8.5), varying between increases and decreases depending on the model and the period. The absence of variation in the extreme events index suggests that, despite changes in the annual accumulation, the frequency of extreme rainfall may remain stable. These results highlight the importance of adaptive strategies for water management and mitigating the impacts of climate variability in the region.

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8 REFERENCES

ANDRADE, EM; SENA, MGT; SILVA, AGR; PEREIRA, FJS; LOPES, FB Uncertainties of the rainfall regime in a tropical semiarid region: the case of the state of Ceará. **Revista Agro@mbiente** , Boa Vista, v. 10, n. 2, p. 88-95, 2016. DOI: 10.18227/1982-8470ragro.v10i2.3500 . Available at: https://doi.org/10.18227/1982-8470ragro.v10i2.3500 . Accessed on: November 20, 2024.

ANA. **Hidroweb v3.3.8361.0** : Historical Series . Brasília, DF: ANA, 2024. Available at: https://www.snirh.gov.br/hidroweb/serieshistoricas . Accessed on: June 7, 2024.

CHOU, SC; LYRA , A.; MOURÃO , C.; DERECZYNSKI , C.; PILOTTO , I.; GOMES , J.; BUSTAMANTE , J .; TAVARES , P.; SILVA , A.; RODRIGUES , D.; CAMPOS , D.; CHAGAS , D.; SUEIRO , G.; SIQUEIRA , G.; NOBRE , P.; MARENGO , J. Evaluation of the Eta Simulations Nested in Three Global Climate Models. **American Journal of Climate Change** , Durham, v. 3, n. 5, p. 438-454, 2014. DOI: 10.4236/ajcc.2014.35039 . Available at: https://doi.org/10.4236/ajcc.2014.35039 . Accessed on: November 13, 2024.

CNPQ. **Climate projections for South America regionalized by the Eta model with bias correction** . Brasília, DF: CNPq, 2024. Available at: https://lattesdata.cnpq.br/dataset.xhtml?persistentId= doi:10.57810/lattesdata / WAVGSL . Accessed on: April 25, 2024.

CEARENSE FOUNDATION FOR METEOROLOGY AND WATER RESOURCES. **Rain Gauges** . Fortaleza: FUNCEME, 2024. Available at: http://www.funceme.br/?page_id=2694 . Accessed on: October 5, 2024.

GÜTSCHOW, J. ; JEFFERY, M.L.; GÜNTHER, A.; MEINSHAUSEN, M. Country-resolved combined emission and socioeconomic pathways based on the

Representative Concentration Pathway (RCP) and Shared Socio-Economic Pathway (SSP) scenarios. **Earth System Science Data** , Munich, v. 13, no. 3, p. 1005-1040, 2021. DOI: https://doi.org/10.5194/essd-13-1005-2021. Available at: https://essd.copernicus.org/articles/13/1005/2021/. Accessed on: October 25, 2024.

GONDIM, RS; SILVEIRA, C.; SOUZA FILHO, F.; VASCONCELOS JUNIOR, F.; CID, D. Climate change impacts on water demand and availability using CMIP5 models in the Jaguaribe basin, semiarid Brazil. **Environmental Earth Sciences** , Bonn , vol. 77, no. 15, p. 1-14 , 2018. DOI: https://doi.org/10.1007/s12665-018-7723-9 . Available at: https://link.springer.com/article/10.1007/s12665-018-7723-9. Accessed on: October 19, 2024.

INMET. **Meteorological Database** . Brasília, DF: INMET, 2024. Available at: https://bdmep.inmet.gov.br/. Accessed on: November 4, 2024.

MESINGER , F.; CHOU , SC; GOMES , JL; JOVIC , D.; BASTOS , P.; BUSTAMANTE , JF; LAZIC , L.; LIRA , AA; MORELLI , S.; RISTIC , I.; VELJOVIC , K. An upgraded version of the Eta model. **Meteorology and Atmospheric Physics** , Bonn, vol. 116, no. 3/4, p. 63-79, 2012. DOI: http://dx.doi.org/10.1007/s00703-012-0182-z. Available at: https://link.springer.com/article/10.1007/s00703-012-0182-z. Accessed on: October 20, 2024.

NUNES, LFCV; MEDEIROS, PHA Historical analysis of drought severity in Ceará: effects of the acquisition of hydraulic capital on society. **Latin American Water Management Journal** , Porto Alegre , v. 17, p. e18, 2020. DOI : https://doi.org/10.21168/rega.v17e18 . Available at: https://www.abrhidro.org.br/SGCv3/publicacao.php?PUB=2&ID=217&SUMARIO=5370. Accessed on: October 20, 2024.

RODRIGUES, GP; BROSINSKY, A.; RODRIGUES, IS; MAMEDE, GL; ARAÚJO, JC Impact of reservoir evaporation on future water availability in northeastern Brazil: a multiscenario assessment. **Hydrology and Earth System Sciences** , Munich , vol. 28, no. 14, p. 3243-3260, 2024. DOI: https://doi.org/10.5194/hess-28-3243-2024 . Available at: https://hess.copernicus.org/articles/28/3243/2024/. Accessed on: October 23, 2024.

SECRETARIAT OF WATER RESOURCES. **Monitored reservoirs register 49% of volume; See situation by Hydrographic Basin** . Fortaleza: SRH, 2024. Available at: https://www.srh.ce.gov.br/reservatorios-monitorados-registram-49-de-volume-veja-situacao-por-bacia-hidrografica/. Accessed on: October 12, 2024.

TAVARES , P.; PILOTTO , IL; CHOU , SC; SOUZA , SA; FONSECA , LMG; CHAGAS , DJ A dataset of high-resolution climate change projections over South America with bias correction. **Derbyana** , São Paulo, v. 45, n. 1, p. 1-28, 2024. DOI: https://doi.org/10.69469/derb.v45.821. Available at: https://revistaig.emnuvens.com.br/derbyana/article/view/821. Accessed on: January 13, 2025.